View metadata, citation and similar papers at core.ac.uk
brought to you by CORE
provided by Archivio istituzionale della ricerca - Politecnico di Milano

A COMPUTATIONAL MODEL OF THE INTERACTION BETWEEN MICROCIRCULATION AND TISSUE INTERSTITIUM

Prediction and Modeling of response to Molecular and External Beam Radiotherapies

Session 3: Methodological aspects of in silico multiparametric modeling

POLITECNICO DI MILANO

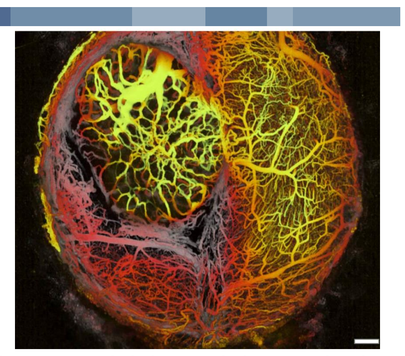
L. Possenti[1], G. Casagrande[1], M.L. Costantino[1] and P. Zunino[2]

1 - Department of Chemistry, Materials and Chemical Engineering “Giulio Natta”, Politecnico di Milano, Italy

2- MOX, Modelling and Scientific Computing, Department of Mathematics, Politecnico di Milano, Italy

Introduction

We present a sophisticated mathematical and computational model for coupled flow, heat and mass transport in the tumor microenvironment and we apply it to study advanced cancer treatments. Such phenomena are at the basis of the exchange of nutrients, wastes and pharmacological agents between the cardiovascular system and the organs. They are particularly interesting for the study of effective therapies to treat vascularized tumors. We develop a model applicable at the microscopic scale, where the capillaries and the interstitial volume can be described as independent structures capable to propagate flow and chemicals.

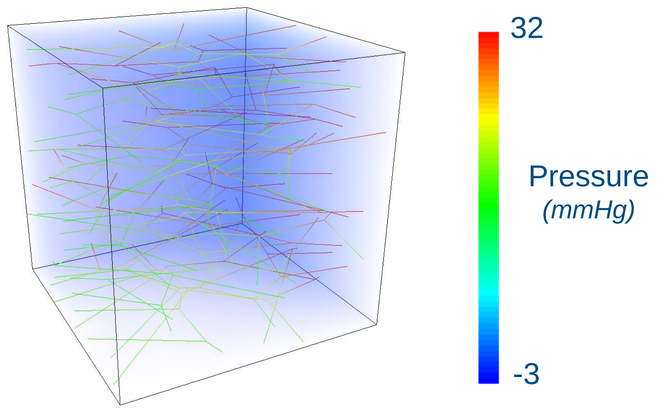


from: steelelabs.mgh.harvard.edu

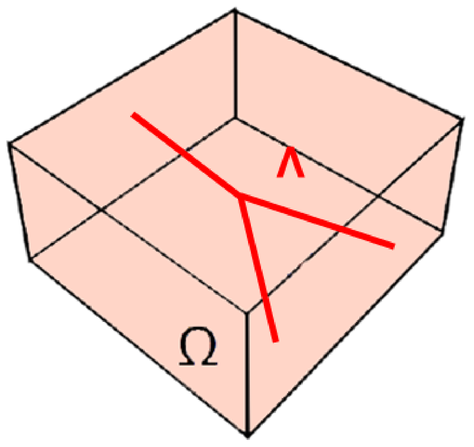
Model

The model has the unique ability of combining the following features: (i) realistic vasculature; (ii) coupled capillary and interstitial flow; (iii) hematocrit dependent flow properties (Fåhræus-Lindqvist effect); (iv) prediction of red blood cells distribution along the vasculature (with plasma skimming effect); (v) coupled capillary and interstitial mass transfer applied to nanoparticles; and (vi) coupled capillary and interstitial heat transfer.

Realistic vasculature *(soon including curvature of vessels)*



Coupled capillary and interstitial flow



Porous media for Ω
(Darcy’s law)

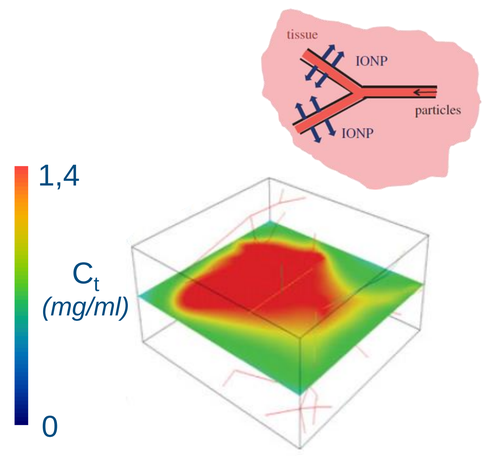
Cylindrical conducts for Λ
(Poiseuille’s law)

Lymphatic drainage included
(non-linear function of fluid pressure)

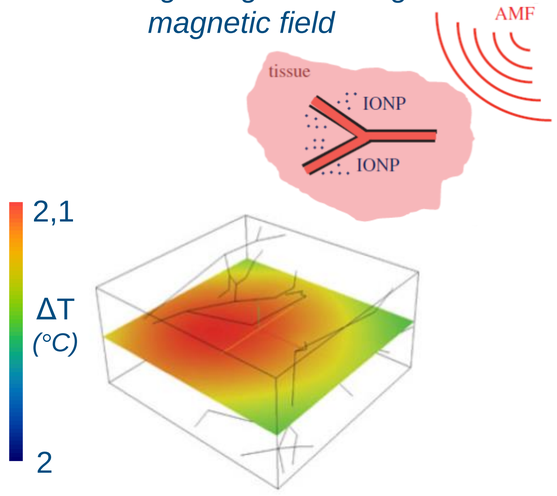
Leakage across capillary wall
(Starling’s equation)

Coupled capillary and interstitial heat transfer

Particles release

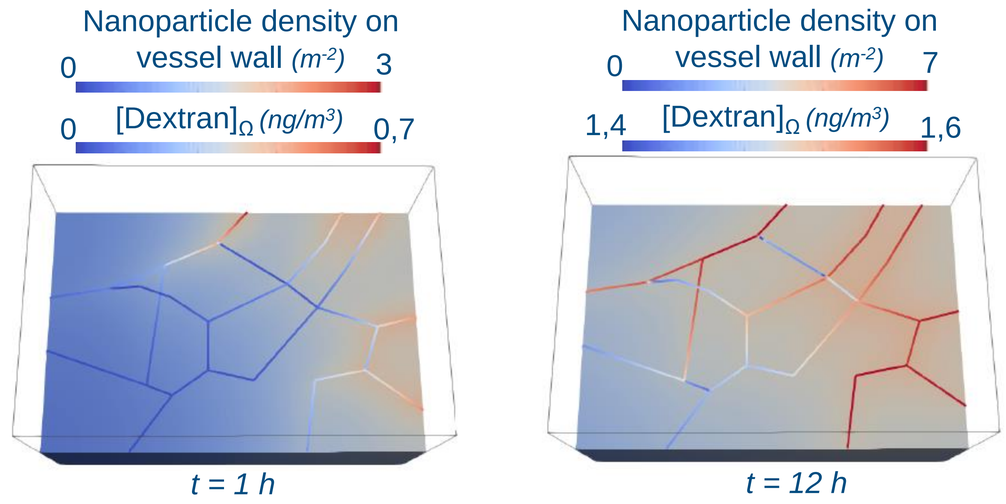


Heating using alternating magnetic field



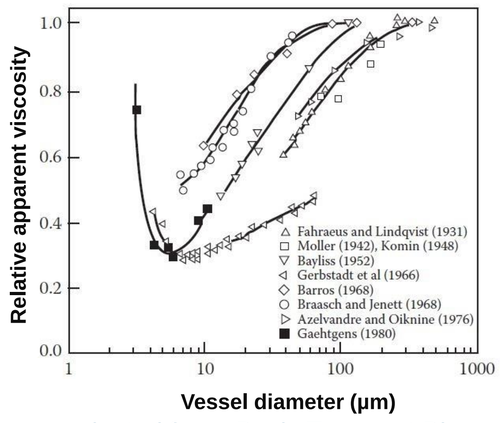
adapted from: Nabil, Decuzzi, Zunino (2015)

Coupled capillary and interstitial mass transfer for nanoparticles

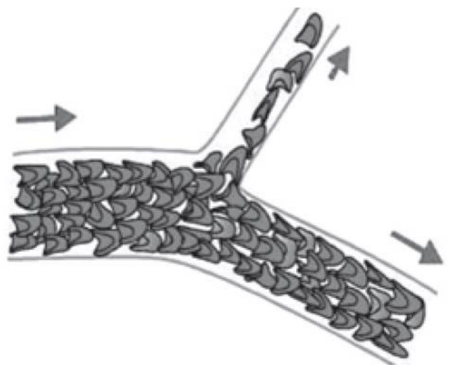


adapted from: Tiozzo (2017)

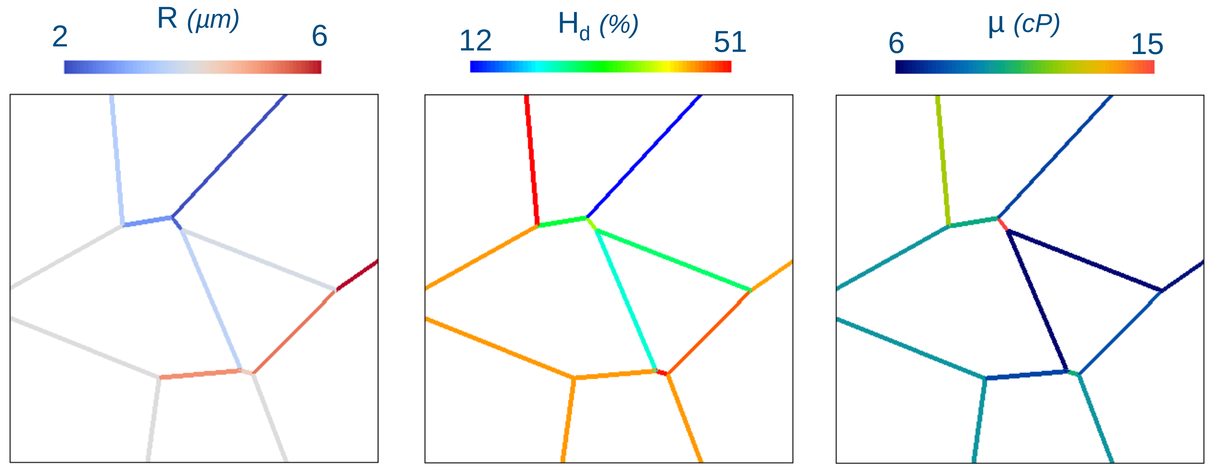
Hematocrit dependent flow properties, including prediction of red blood cells distribution along the vasculature



adapted from: Basic Transport Phenomena in Biomedical Engineering 3/e (2012)



adapted from: Pries et al. (2005)



adapted from: Di Gregorio (2017)

Conclusion and applications

The model can be applied to **compare various treatment options**, such as drug delivery using drug bolus injection and nanoparticles injection into the blood stream. The computational approach is suitable for a **systematic quantification of the treatment performance**, enabling the **analysis of interstitial drug concentration levels, metabolization rates and cell surviving fractions**.

References

- Possenti, Casagrande, Costantino, Zunino; Int J Artif Organs; 40(8): 382 - 428, 2017
- Di Gregorio; Master thesis, Politecnico di Milano, AY 2016/2017
- Tiozzo, Master thesis, Politecnico di Milano, AY 2016/2017
- Decuzzi. ACS Nano 10(9), 8133-8138, 2016
- Nabil, Zunino. Royal Society Open Science, 3 (9), art. no. 160287, 2016
- Nabil, Decuzzi, Zunino. Royal Society Open Science, 2 (10), 2015
- Cattaneo, Zunino. International Journal for Numerical Methods in Biomedical Engineering, 30 (11), 1347-1371, 2014
- Cattaneo, Zunino. Networks and Heterogeneous Media, 9 (1), 135-159, 2014
- Pries e Secomb. AJP.Heart and circulatory physiology 289.6, 2005

Contact address: luca.possenti@polimi.it